REMARKS

By this Amendment claims 66-74 and 84-91 have been canceled, claims 38, 56, 57, 75-78, 92, 99 and 100 have been amended, and new claims 108-154 have been added. Entry requested.

In the outstanding Office Action the examiner has rejected claims 38-54, 56-63 and 66-107 under 35 U.S.C. §103(a) as being unpatentable over Ishikawa et al. in view of Krames et al. This rejection is incorrect.

Ishikawa et al.

Ishikawa et al. teach increasing the efficiency with which an LED converts electrical enerby by generating the light of the LED in the form of a ring. To achieve the ring-light pattern, it is necessary to place at the center of the LED chip a first electrode 125 connected to one of the semiconductor layers. It is also necessary to provide a second electrode, surrounding the first electrode, which is connected to another of the semiconductor layers. The central electrode may be in a cavity provided for the electrode, as in Fig. 7 or on a mesa, as shown in Fig. 6. The region of light-generation of the LED chips is illustrated in Fig. 5 by narrow ring annotated "LIGHT EMITTING PORTION". Only a fraction of the chip generates light. The rest of the chip is wasted. Thus, Ishikawa et al. aim to improve the conversion efficiency of an LED by sacrificing a large part of the LED chip. By contrast, an important aim of applicant's invention is to improve the conversion efficiency of an LED without sacrificing a large part of the LED chip.

Another important aim of applicant's invention (see page 2, lines 4-16 and 23-26) is to ensure that each of the p- and the n-terminal

electrodes 11, 12 of the LED occupies a substantially negligible proportion of the top of the LED so that a rectangular area of uniform light can be projected from the lamp. Ishikawa et al. do not achieve this.

In the embodiments having the central cavity, Ishikawa et al. do not provide a conductor layer (such as a light passing conductor layer) that covers the top surface and energizes substantially all of the active region of the LED. To do so would be contrary to their teaching of increasing efficiency of light production. They teach increasing the efficiency by confining recombination, and therefore light generation, to the "LIGHT EMITTING PORTION" indicated by the oval in FIG. 4 and the corresponding ring in FIG. 5. The sheet resistances of the semiconductor n- and p-layers are controlled to achieve the desired ring-shaped confinement, as indicated in column 7, lines 25-32.

Applicant illustrates in FIG. 4 a ray 28 passing through cavity wall 26 being redirected for output by a reflector 16 that is on the semiconductor. There is no such teaching given by Ishikawa et al. Looking at their FIG. 48, lateral light propagating away from the central cavity is redirected for output by a reflector 92 which is external to the semiconductor. The is no teaching of lateral light propagating towards joint 99 in the cavity being either harvested or redirected for output.

Thus, the Ishikawa et al. arrangement with the central cavity into layers 124, 123, 122 neither generates as much light as possible from an LED, nor provides a full uniform lighted area, nor exploits a conductor layer, nor provides on the semiconductor arrangements for redirecting lateral light for output.

Ishikawa et al. do not each providing light-extraction surfaces spread about the LED for extracting the light (whereby the efficiency of the LED can be maximized, the width of the LED can be made large, for example 5 millimetres, and the illumination can be full and uniform).

Ishikawa et al. provide conductors arranged to produce only ring-light. By contrast, with the aid of distributed conductors, the whole of applicant's arrangement generates light. Applicant states in the next to last paragraph on page 6 that by conductors 16 the distribution of current, and hence the light generated, throughout the chip top is made more uniform.

The Fig. 7 arrangement cited by the examiner uses a Bragg reflector for reflecting downward vertical light back up, so that the vertical light is not absorbed in GaAs substrate 121. A Bragg reflector works by interference, and for this reason it is not effective for all angles of incidence to it. A Bragg reflector optimized for reflecting vertical light would be substantially light-passing to light at 45 degrees incidence, for example, and such light passing through the Bragg would be lost by absorption in the GaAs substrate 127. Thus the Bragg reflector is not a satisfactory device for guiding light. Furthermore, Bragg reflectors are costly to make.

Krames et al.

The objective of Krames et al. is to increase the efficiency of an LED. This is achieved by arranging that an LED chip has a thick top window layer, and that the outer sides of the LED are oblique to the active region 11 instead of being at right angles to the active region. The

overall improvement in efficiency can be of the order of 1.4 (col. 5, lines 18-21).

To achieve the oblique sides, part of the LED chip, which is divided form a wafer, must be sacrificed. The consequence of the sacrifice is that, for a given chip-cost the chip produces only about 40% to 53% of the light of a conventional chip having vertical outer sides. This is indicated by Krames et al. In Fig. 8. Fig. 8 plots "flux per unit cost" against the "aspect ratio". The aspect ratio is the ratio of the top window thickness "h" to the width of the active "w" (the aspect ratio is referred in col. 7, lines 65, 66).

The flux per unit cost for a conventional chip is referred to in col. 8 lines 6, 7 as being 1, for comparison.

Thus, for the same chip cost, the Krames et al. LED has considerably less light output compared to a conventional LED. This increase in chip cost for producing a given amount of light is contrary to the purpose of applicant's invention.

As further indication that the chip cost is increased by the Krames et al. arrangement, they state in col. 7 lines 36-38:

> "for certain systems applications it is acceptable to triple the die cost in exchange for 40% gain in efficiency..."

Apart from the aforementioned increase in cost, the Krames et al. arrangement also suffers from the disadvantage of requiring a thick window layer for light extraction.

The plot of Fig. 8 shows that for a flux/cost ratio of 45% h (h is synonymous with h_T) is half the width of active region 11. Thus for an

active region width of 20 mils the top window thickness h (h_T) is 10 mils (i.e. 250 microns).

If, for example the active region width is doubled, the window thickness also doubles, to 500 microns, for the same "45%h" flux cost ratio.

By comparison, applicant's invention can function without a window layer. Furthermore the width of the active region in applicant's invention can be increased, even to 5000 microns or more, without requiring any increase at all in the thickness of the LED chip.

Further still, unlike the Krames et al. teaching, applicant's invention teaches how to improve the efficiency of an LED device without having to sacrifice a major part of the LED device.

Kim

Kim (US 3,900,863) describes an LED structure having an array of facet grown LED islands 18, grown over a masked n-doped substrate 10. Light is generated by active region 22a. Kim does not teach providing a reflector below active region 22a for harvesting downward light. Without harvesting the downward light half the light generated is lost. For a high power lamp it is important to harvest all the light.

There is no teaching of there being any guided light in the humped LED 18. There is no teaching of using intercepted guided light to increase the efficiency of an LED.

There are no cavities in the Kim structure that each contain a metal part feeding the lower semiconductor layer.

In the Kim structure light extraction is by the upper and side surfaces of the humps. None of these light passing surfaces cut into either the p-layer or the n-layer.

The Kim arrangement requires the complication of providing an active region that is humped. There is no need for such complication in applicant's lamp.

Wickens

Wickens describes a display (Fig. 5), with each of the pixels I-IX being as portrayed in section in Fig. 2 (Step E). Fig. 3 is a plan view of the pixel. There is no teaching of how to provide a high power LED lamp.

Light is generated in a pixel at the junction between semiconductor p-zone 32 and the much wider n-zone 30. Isolation zones 28 surround the pixel to isolate it from its neighbors. The generated light is output via a dielectric Fresnal lens 38, which can be of SiO_2.

Very little of the Wickens device generates light, as is evident from Fig. 2 E. Only the p-n junction at 32 produces light.

Furthermore, the Wickens device is formed in a silicon wafer (column 3, lines 61-64; column 4 lines 7-10). Silicon is highly absorbent to visible light, and therefore visible generated by the Wickens device, if any, would be feeble.

Wickens doe s not teach how to make a single-chip lamp that can replace a cluster lamp (Such as the cluster lamp of US 6,045,240, cited by the Examiner in the parent application). Furthemore, Wickens does

not suggest exploiting intercepted guided light to improve light output from an LED.

Komoto

Komoto describes an LED, Figs. 3A-3D, having a ring-groove 8 close to the four sides 10 of the LED. The purpose of the ring-groove is to prevent lateral light generated in the LED from "leaking" out of the LED (see column 2 lines 50-56 and column 6 lines 44-54). This suppression of the lateral light is contrary to the teaching of applicant's invention, which teaches harvesting lateral light.

Regarding Komoto, the examiner refers at the bottom of page 8 of the office action to light:

> "—a part of which propagates parallel to the active region and undergoes multiple internal reflections and is output through the light-extraction surfaces (side surfaces of the cavities (as evidenced by U.S. Patent 5,753,940 to Komoto)."

There is no reference in Komoto of multiple internal reflections, nor is there any teaching of light-extraction surfaces for enhancing output of lateral light. As mentioned above, Komoto aims to prevent lateral light from escaping the LED.

Regarding Claim 38 (amended)

The examiner refers to column 9, lines 25-40, and FIG. 7 of Ishikawa et al. and states (at the bottom of page 5 of the Office Action):

> "Ishikawa et al. further disclose the LED lamp comprising of plurality of cavities extending from the upper face into the semiconductor structure, each containing a metal part 125.. "

It is respectfully submitted that there is only one cavity, and only the one metal part 125 (around which the light-ring is generated). The

purpose of the Ishikawa et al. cavity is to enable the ring-light to be created.

The examiner also states on page 6 of the Office Action:

> "Krames et al. in analogous art of semiconductor light-emitting device disclose (abstract) the side surfaces of the cavities are formed at preferred angle --".

It is respectfully submitted that Krames et al. do not teach providing any cavities in the semiconductor that are distant from the outer side faces.

Krames et al. teach using a thick window layer with slanted outer sides. Ishikawa et al. teach providing a thin ring of light. Combining the thick window teaching with the ring-light teaching would not result in Applicant's invention.

Neither Ishikawa et al. nor Krames et al. teach replacing a cluster lamp, of for example several watts, with a single light emitting device.

It is respectfully submitted that claim 38 (amended) is allowable over Ishikawa et al. and Krames et al. for one or more of the reasons given above.

Regarding Claim 56 (amended)

Neither Ishikawa et al. nor Krames et al. provide light extraction surfaces that are distant from the outer sides and distributed about the LED, so that trapped light can be extracted from all portions of the LED. Light extraction is of major importance in LEDs.

In order to improve light extraction of their LED, Krames et al. deliberately sacrifice a large part of the LED when cutting it from the wafer.

Krames et al. do not teach providing light extraction surfaces that are distant from the outer side faces of the LED and inclined to the semiconductor layers.

Unlike Applicant's objectives and teaching, the Ishikawa et al. arrangement with the central cavity does not provide an LED having a major face substantially all of which is luminous, and does not provide a solution for replacing cluster lamps (that use hundreds of LEDs) with a lamp having just one LED.

Ishikawa et al. provide conductors arranged to produce only ring-light. By contrast, with the aid of distributed conductors 16, the whole of Applicant's arrangement generates light. Applicant states in the last but one paragraph on page 6 that by conductors 16 the distribution of current, and hence the light generated, throughout the chip top is made more uniform.

As to Komoto, Komoto teaches suppression (i.e., sacrifice) of lateral light and does not encourage extraction of lateral light.

It is respectfully submitted that claim 56 (amended) is allowable over Ishikawa et al., Krames et al., and Komoto for one or more of the reasons given above.

Regarding Claim 60

Claim 60 was rejected as being unpatentable over Ishikawa et al. in view of Krames et al.

It is respectfully submitted that claim 60 is patentable for the following reasons:

- Whereas claim 60 specifies refractive indexes, Ishikawa et al. do not discuss the refractive index of either a reflective layer or a substrate.

- A Bragg reflector is not satisfactory for guiding light, as discussed in paragraph 1.11 above, much of the lateral light can pass through the Bragg and be lost in GaAS substrate 121.

- Ishikawa et al. do not provide a conductor layer covering and in electrical contact with the upper semiconductor layer 124. Such a layer would interfere with their primary objective, as discussed in paragraph 1.6 above.

- Ishikawa et al. do not teach using a plurality of spaced-apart conductors on one of the layers, at least one of which appears between light-generating portions. Neither do Krames et al. No part of the Ishikawa et al. conductor 126 appears between light generating portions. There is no teaching that ohmic contact part 129 is a conductor; the corresponding contact part 139 in FIG. 8 is of p-type ZnTe semiconductor (see column 11, line 24).

- Neither Ishikawa et al. nor Krames et al. teach how to improve the efficiency of an LED device without having to sacrifice a major part of the LED device.

- Ishikawa et al. do not teach providing several light-extraction surfaces distant from the outer side faces (see paragraph 1.9 above). Nor do Krames et al.

It is respectfully submitted that for the above reasons claim 60 is allowable over Ishikawa et al., Krames et al.

Regarding claim 64

The Examiner states at the bottom of page 15 of the Official Action:

> "Wickens discloses first and second set of LED portions connected in parallel."

It is respectfully submitted that Wickens does not show LEDs connected in parallel. LEDs I, II, III have a common cathode which is connected to terminal "A", but the anodes of these three LEDs are not connected together. Wickens does not provide either series or parallel connection of any of the LEDs I-IX.

None of the LEDs I-IX has a cathode that is metallically connected to the anode of another of the LEDs.

It is respectfully submitted that for this reason claim 64 is allowable over Ishikawa et al., Krames et al. and. Wickens.

Regarding Claim 75 (amended)

Neither Ishikawa et al. nor Krames et al. teach having a plurality of grooves provided for the purpose of extracting light from the semiconductor structure.

Neither Ishikawa et al. nor Krames et al. teach providing a groove with a side wall that emits light that is reflected by a metallic reflector in the groove that is inclined to the reference plane.

It is respectfully submitted that for these reasons claim 75 (amended) is allowable over Ishikawa et al. and Krames et al.

Regarding Claim 77 (amended)

Neither Ishikawa et al. nor Krames et al. teach having a plurality of grooves provided for the purpose of extracting light from the semiconductor structure.

Neither Ishikawa et al. nor Krames et al. teach providing a groove with a side wall that emits light that is reflected by a metallic reflector in the groove that is inclined to the reference plane.

Applicant's FIG. 4 illustrates consecutive reflections of ray 28. There is nothing corresponding to this in either Ishikawa et al. or Krames et al.

The double reflection is important as it facilitates outputting ray 28 vertically, and without ray 28 re-entering the semiconductor.

It is respectfully submitted that for these reasons claim 77 (amended) is allowable over Ishikawa et al. and Krames et al.

Regarding Claim 78 (amended)

Neither Ishikawa et al. nor Krames et al. teach providing metallic reflectors on the semiconductor structure that are distant from the outer side faces and arranged for redirecting light leaving the semiconductor.

Ishikawa et al. central device 105 is a chip terminal, and is covered by bonding metal 99 (FIG. 48). There is no teaching of redirecting light entering the cavity.

Neither Ishikawa et al. nor Krames et al. teach having a plurality of grooves provided for the purpose of extracting light from the semiconductor structure.

The grooved arrangements illustrated in applicant's FIGS. 2, 3 4, 5 provide an LED in which light-extraction is improved without necessarily sacrificing a major part of the LED. This is unlike the teachings of Ishikawa et al. and Krames et al.

It is respectfully submitted that for these reasons claim 78 (amended) is allowable over Ishikawa et al. and Krames et al.

Regarding Claim 81

Neither Ishikawa et al. nor Krames et al. teach having a plurality of trenches provided for the purpose of extracting light from the semiconductor structure.

Neither Ishikawa et al. nor Krames et al. teach having a plurality of trenches provided for extracting light from the semiconductor structure in combination with arranging that one of the trenches is inclined to another by an acute angle.

Applicant describes in the second paragraph on page 12, with reference to FIGS. 6a, 6b, additional improvement to light extraction that can be achieved by using trenches inclined to each other by an acute angle, as provided in FIG. 5.

Maximizing light output from an LED is a very important objective and applicant discloses how to achieve this objective without sacrificing a major part of the LED. The Ishikawa et al. and Krames et al. arrangements sacrifice a major part of the LED.

It is respectfully submitted that for these reasons claim 81 is allowable over Ishikawa et al. and Krames et al.

Regarding Claim 92 (amended)

Neither Ishikawa et al. nor Krames et al. provide light extraction surfaces that are distant from the outer sides and distributed about the LED.

Unlike Applicant's objectives and teaching, the Ishikawa et al. arrangement with the central cavity does not provide an LED having a major face substantially all of which is luminous, and does not provide a

solution for replacing cluster lamps (that use hundreds of LEDs) with a lamp having just one LED.

In order to improve light extraction Krames et al. deliberately sacrifice a large part of the LED when cutting it from the wafer.

The Krames et al. arrangement requires a thick window layer, the thickness increasing as the chip width is increased. There is no such requirement with Applicant's invention.

It is respectfully submitted that for these reasons claim 92 (amended) is allowable over Ishikawa et al. and Krames et al.

Regarding Claim 100 (amended)

Neither Ishikawa et al. nor Krames et al. disclose a plurality of cavities that are introduced for light extraction and distributed about the structure.

Unlike Applicant's objectives and teaching, the Ishikawa et al. arrangement with the central cavity does not provide an LED having a major face substantially all of which is luminous, and does not provide a solution for replacing cluster lamps (that use hundreds of LEDs) with a lamp having just one LED.

As discussed above the use of a conductor layer covering the upper semiconductor layer of the Ishikawa et al. LED that has the cavity would go against their teaching.

In order to improve light extraction Krames et al. deliberately sacrifice a large part of the LED when cutting it from the wafer.

The Krames et al. arrangement requires a thick window layer, the thickness increasing as the chip width is increased. There is no such

requirement with Applicant's invention. A thick window is costly to provide.

It is respectfully submitted that for these reasons claim 100 (amended) is allowable over Ishikawa et al. and Krames et al.

Regarding new Claim 108

Neither Ishikawa et al. nor Krames et al. provide light extraction surfaces that are distant from the outer sides and distributed about the LED.

Claim 108 specifies an opaque reflector covering a dielectric layer that covers a conductor layer that is spread over the upper semiconductor layer. By this stacked arrangement upward vertical light can be harvested by reflection at the opaque reflector while lateral light can be reflected by the dielectric layer. The arrangement reduces light losses since oblique light reaching the dielectric layer is 100% reflected. There is no teaching by either Ishikawa et al. or Krames et al. of such a stacked arrangement over the upper semiconductor layer.

It is respectfully submitted that for these reasons claim 108 is allowable over Ishikawa et al. and Krames et al.

Regarding new Claim 111

Neither Ishikawa et al. nor Krames et al. provide a semiconductor structure that has several light-generating portions each of which is substantially surrounded by light-diverting surfaces that extend from the upper face into the lower semiconductor layer.

Neither Ishikawa et al. nor Krames et al. disclose distributed opaque conductors on either of the semiconductor layers. Neither Ishikawa et al.

nor Krames et al. suggest replacing a cluster lamp, of for example several watts, with a single light emitting device.

It is respectfully submitted that for these reasons claim 111 is allowable over Ishikawa et al. and Krames et al.

Regarding new Claim 125

Neither Ishikawa et al. nor Krames et al. teach providing a semiconductor structure that has several inclined light-extraction surfaces distributed about the semiconductor structure and distant from the outer side faces.

Neither Ishikawa et al. nor Krames et al. teach providing a plurality of spaced-apart conductors for energizing the lower semiconductor layer that are distant from the outer side faces and each positioned between light generating portions of the semiconductor structure. Neither Ishikawa et al. nor Krames et al. suggest replacing a cluster lamp, of for example several watts, with a single light emitting device.

It is respectfully submitted that for these reasons claim 125 is allowable over Ishikawa et al. and Krames et al.

Regarding new Claim 136

Neither Ishikawa et al. nor Krames et al. teach providing a semiconductor structure that has several inclined lightextraction surfaces distributed about the semiconductor structure and distant from the outer side faces.

Neither Ishikawa et al. nor Krames et al. teach providing trenches extending from the upper semiconductor layer and containing metal

tracks in electrical contact with the lower semiconductor layer, the tracks delivering current together.

It is respectfully submitted that for these reasons claim 125 is allowable over Ishikawa et al. and Krames et al.

No combination of Ishikawa et al. and Krames et al. would suggest the claimed invention.

The examiner is hereby authorized to charge any additional claims fee to our Deposit Account 04-2223.

Respectfully submitted,

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